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PHYSICAL CHEMISTRY.—*Microstructural changes accompanying the annealing of bronze.* HENRY S. RAWDON, Bureau of Standards.[1]

A study of the structural changes in bronze induced by annealing was made to supplement the investigation of the standard zinc-bronze (88 Cu, 10 Sn, 2 Zn) recently carried out at the Bureau of Standards. The various changes together with the temperatures at which such changes are completed were determined.

After casting, the alloy exhibits a complex structure comprising a dendritic matrix consisting of a solid solution of tin (and zinc) in copper, in which are embedded numerous particles of a hard and brittle eutectoid similar in structure and formation to pearlite in steel. Upon annealing, the alloy is first rendered homogeneous by the absorption of the eutectoid by the matrix and the disappearance of the dendritic structure of the same matrix by diffusion. If the alloy has received no deformation previous to annealing, no other changes are observed, the crystal or "grain" size remains unchanged. The characteristic polyhedral twinned crystals seen in annealed brass and bronze rich in copper are obtained only after the structure has been distorted. Samples which had been cooled in a very drastic manner, thus inducing severe internal stresses, behaved similarly upon annealing to those which had been mechanically deformed before annealing.

[1] To appear in full as a Scientific paper of the Bureau of Standards.

BECAUSE OF SURFACE OXIDATION THE MEASURED THICKNESSES DO NOT REPRESENT THE TRUE DEPTH TO WHICH THE METAL WAS WORKED. AVERAGE WEIGHT OF SAMPLE, 20 GRAMS

SPECIMEN NO.	MECHANICAL TREATMENT	THERMAL TREATMENT	THICKNESS OF "RECRYSTALLIZED" LAYER[3]	AMOUNT OF EUTECTOID[1]	DENDRITIC STRUCTURE	REMARKS
			mm.			
B 1	Two hexagonal bars 1 in. on a face were cast in green sand. These were turned down to ¾ in. diameter and cut into sections ¾ in. long.	1 hr. 400°C	0.056	85.0	Very evident.	Eutectoid was found shattered to a depth of 0.10 mm, 0.113, 0.15
B 2		2 hr. 400°C	0.076	82.0		
B 3		4 hr. 400°C	0.088	85.5		
B 4		Unheated	none	0.83		Aver. 0.135
B 6		8 hr. 400°C	0.07	76.5	The outlines of the cores are indistinct, diffusion has begun.	
			Av. 0.072			
B 7		1 hr. 600°C	0.161	41.5	Very evident.	
B 8		2 hr. 600°C	0.181	19.0		
B 9		4 hr. 600°C	0.163	12.0	Cores are quite faint and not continuous.	
B 10		8 hr. 600°C	0.183	6.5		
			Av. 0.172			
B 11		1 hr. 800°C	0.34	4.0	Dentrites are found in some grains, and are quite plainly seen in oblique illumination.[2]	
B 12		2 hr. 800°C	0.33	0.4	Very faint trace of cores under oblique illumination.	
B 13		4 hr. 800°C	0.34	0.0	All dendritic structure is erased.	
B 14		8 hr. 800°C	0.37	0.0		
			Av. 0.345			

[1] To obtain an approximate quantitative expression of the rate of absorption of the eutectoid, the number of inclusions in the successive microscope fields taken contiguously along a diameter of the sample (magnification 100×) was counted. On account of the difference in size of the particles, this method is a rough approximation only.

[2] When the dendritic structure appears to have disappeared entirely, upon examination under vertical illumination, with oblique illumination it is still to be seen.

[3] The thickness of the recrystallized layer was in all cases measured directly by means of a micrometer ocular.

The samples used were small cylinders, the surface layer of which had been distorted by machining in the lathe. These were annealed for periods of: 1, 2, 4, and 8 hours at 400°, 600°, and 800°C. The data tabulated below for one series indicate the general nature of the observations made and the results obtained.

The constancy of the thick ess of the recrystallized layer (different for different temperatures) is very striking. Though the crystals in this layer of recrystallized metal increase in size upon annealing, there appears to be no appreciable increase in thickness of the layer itself. The process is not a progressive one from exterior inward, but begins simultaneously throughout the layer which is capable of being affected at that temperature. The results obtained are in support of, and in accordance with, Tammann's theory of the recrystallization of "cold-worked" metals upon heating.

GEOLOGY.—*The geologic significance of the growth-rate of the Floridian and Bahaman shoal-water corals.*[1] THOMAS WAYLAND VAUGHAN, Geological Survey.

Except to allude to the continuation of the experiments and observations, no specific report on the results of the study of the growth rate of corals has been published since the one in Year Book No. 10 of the Carnegie Institution of Washington, pages 148–156, Plates 4–6, where all data then available on the size of year-old corals were presented. The technique for rearing and planting corals and that for measuring corals growing under natural conditions are described in the Year Book referred to and in Year Book No. 9, pages 136–144, Plate 1. The descriptions there given need not be repeated.

As the object of the investigation should be made clear, it should here be stated that stony corals are not suitable subjects

[1] Published by permission of the President of the Carnegie Institution of Washington and of the Director of the U. S. Geological Survey. The field studies were made under the auspices of the Department of Marine Biology of the Carnegie Institution of Washington while the office facilities were furnished by the U. S. Geological Survey. A fuller account of these investigations will appear in the Year Book of the Carnegie Institution of Washington for 1915.

for a critical study of the laws of growth rate. The proportion of living tissue to the stony skeleton is relatively small and as the skeleton after very young stages usually is not entirely covered by the living soft parts, organisms may attach themselves to it and increase its weight, or boring organisms may enter it, begin its destruction, and decrease its weight. As many boring organisms have calcareous tests, they destroy a part of the original skeleton and add the weight of their own. Minute algae, as Duerden has shown, bore into the skeleton and ramify through it almost or quite to the boundary of the living soft parts. Weights obtained from specimens cemented to discs are subject to all the sources of inaccuracy enumerated above and also to the practical inability of restoring the disc to its initial condition after affixing and planting a specimen, because of organisms attaching themselves to its surface. These remarks make it clear that the object of the investigation is not to make a contribution to the laws governing growth-rate, although some of the principles of growth-rate of some species have been ascertained. The actual object of the investigation has been to aid in understanding the relative amount of work stony corals may do as constructional geologic agents, and especially in the formation of those calcium carbonate structures designated "coral reefs."

In order properly to evaluate corals as constructional agents, the subject needs to be studied from at least five different viewpoints, viz.: (1) In dealing with sediments uplifted above the sea, the quantity of material contributed by corals and that contributed by other agents must be estimated and the respective proportions determined; (2) in coral reef areas, the ratio of the area covered by corals to that not covered by them should be estimated; (3) the relations of coral reefs to continuity and discontinuity of marginal submarine platforms must be ascertained; (4) marine bottom deposits must be analyzed according to the source of the material, and the percentage of the calcium carbonate contributed by the different agents estimated; (5) the rate of growth of corals needs to be known, especially for the light it may throw on the rate of reef formation.

That corals have been tremendously over-evaluated is established. In this connection, reference may be made to Murray and Renard's[2] description of their coral sand and coral mud and to some analyses Quin[3] has made of the calcareous sand on the shores of St. Croix Island, Danish West Indies.

From the table on page 596 it will be seen that there is no single formula for the growth-rate of corals, as the rate of growth is different for different species, and in each species it varies in accord with differences in local ecologic conditions. In order to understand the factors controlling growth-rate, the ecologic factors common to the entire reef-tract should be ascertained, and each species should be studied to discover the subordinate ecologic conditions of its more restricted habitat. Investigations of the Florida reef-tract along both these lines have been made, and some of the results have been presented in my previous papers.

Observations and experiments were conducted on the growth-rate of Tortugas corals as follows:

(1) Colonies obtained from planulae whose history was known. They were planted (a) off the northwest face of Fort Jefferson moat-wall and (b) on the reef off the northwest side of Loggerhead Key.

(2) Colonies cemented to tiles. These were planted (a) off the northwest face of Fort Jefferson moat-wall and (b) on the reef off Loggerhead Key.

(3) Colonies naturally attached: (a) in Fort Jefferson moat; (b) on piers of the Fort Jefferson wharf; (c) on the outside of the northwest face of the Jefferson moat-wall; (d) on the reef off the northwest face of Loggerhead Key.

The observations and experiments in the Bahamas were made on the leeward side of the north end of a small island, known as Golding Cay, which is on the east side of Andros Island at the mouth of South Bight. The specimens included, (a) those cemented to tiles and planted, (b) those living naturally attached.

[2] Challenger Repts., Deep-sea deposits, p. 246. 1891.
[3] Quin, John T. The building of an island, p. 15. 1907.

The size of the colonies of all species of corals seems limited, but some attain large dimensions, 2 to 3 meters or even more in diameter, and nearly as much in height, while other species are adult when a diameter of 35 to 50 mm. has been reached. Records of two species, *Favia fragum* and *Maeandra areolata* illustrate relatively rapid growth for the first 2 to 4 years, after which it decreases. Other species, for instance *Orbicella annularis* and *Maeandra strigosa* are not so limited in size. Ramose corals increase in dimensions more rapidly than massive species: while of the former, the growth rate of species with perforate, loose-textured skeletons is more rapid than that of species with dense skeletons. In general the more massive and the denser the corallum, the slower the growth; while the more ramose and the more porous the skeleton, the more rapid the growth.

TABLE OF INDICATED AVERAGE ANNUAL GROWTH-RATE

When practicable two diameters at right angles to each other were measured in successive years, and the increments were ascertained by subtracting the next earlier from the later measurements. All increments for each species at each station were added together and divided by the number of the annual increments entering into the computation. The averages for height were similarly determined. As the records are for annual growth-rate, each of the Bahama records is counted as 2, as each of those represents a period of 2 years.

It should be said regarding the nomenclature of the species that the specimens designated *Mussa* (*Isophyllia*) *dipsacea* Dana may include colonies of *M.* (*Isophyllia*) *fragilis* Dana. The specimens referred to *Porites clavaria* Lamarck may include more than one species of similar growth facies.

As has been stated, the primary object of this investigation was to get an approximate measure of the rate at which corals might build reefs. In order to make this estimate, the true reef corals must be considered separately from those which live in other habitats. The reef species *par excellence* in the Recent and Pleistocene reefs of Florida and the West Indies is *Orbicella annularis;* after it in importance are *Maeandra strigosa, M.*

labyrinthiformis, and *Siderastrea siderea*. Other corals, the most important of which is *Porites astreoides*, with *Agaricia* and *Favia fragum* of secondary importance, occur in the area intermediate between the prominent heads. In some areas *Acropora palmata* is the dominant species. The massive heads form the strong frame work of the reef, with infilling by other corals and other organisms. Therefore the upward growth rate of *Orbicella annularis* on the reef is critical. The data on it will be repeated:

Upward growth-rate of Orbicella annularis

Location	Annual average mm.
Ft. Jefferson, tiles outside moat wall	6.57
Loggerhead Reef, tiles	5.28
Loggerhead Reef, nat. att	6.80
Golding Cay, tiles	5.67
Golding Cay, nat. att	5.00

The highest figure is for naturally attached specimens on Loggerhead Reef, but the average is based on only 5 measurements which are not so accurate as those of specimens on tiles. The specimens attached to tiles all thrived and gave an annual average of 5.28 mm. for 14 measurements; while the Golding Cay specimens, which also thrived, gave an annual average of 5.67 mm. for 6 specimens, 2 years growth each. An estimate of 6 mm. for upward growth per year is probably somewhat liberal. This would indicate for an upward growth of a foot, $\frac{25.4 \times 12}{6} =$ 50.8 years. Should 7 mm. be taken as the average the rate would be 1 foot in 43.54 years. Using these figures as the basis of a further computation, a reef by the continuous upward growth of corals might attain at a rate of 6 mm. per year a thickness of 25 fathoms = 150 feet in 7620 years; and at a rate of 7 mm. per year it might attain the same thickness in 6531 years.

Should the growth rate of *Acropora palmata* be taken as a measure, the time to accumulate such a thickness would be considerably less. This species forms spreading, palmate fronds, rising from stout bases. As age advances the fronds thicken and can withstand the pounding of surf and breakers. The average upward growth is between 25 and 40 mm. per year,

Indicated average annual growth-rate of Floridian and Bahaman shoal-water corals

(NOTE.—Nat. att. = naturally attached. Note[1] in table, accuracy or record doubtful; note[2] tape-line measurements, accuracy somewhat doubtful)

NAME	STATION	INCREASE IN DIAMETER		INCREASE IN HEIGHT	
		Amount	No. of records as basis for estimate	Amount	No. of records as basis for estimate
		mm.		*mm.*	
Oculina diffusa Lam.	Ft. Jefferson, tiles outside moat wall	19.28	7	7.5	2
Oculina diffusa Lam.	Ft. Jefferson moat, nat. att.	10.25	4	12.70	5
Oculina diffusa Lam.	Ft. Jefferson wharf, nat. att.	29.57	28	22.61	13
Eusmilia fastigiata (Pallas)	Ft. Jefferson, tiles outside moat wall	9.61	22	4.5	10
Eusmilia fastigiata (Pallas)	Ft. Jefferson wharf, nat. att.	10.62	19	7	4
Eusmilia fastigiata (Pallas)	Loggerhead Key, reef, nat. att.	21	1	—	—
Dichocoenia stokesi M. Edw. & H.	Ft. Jefferson moat, nat. att.	6.67	12	5.2[1]	—
Dichocoenia stokesi M. Edw. & H.	Golding Cay, tiles	6.29	24	2.2	10
Dichocoenia stokesi M. Edw. & H.	Golding Cay, nat. att.	2	4	2	2
Dendrogyra cylindrus Ehr.	Golding Cay, tiles	7	16	10.375	8
Orbicella annularis (Ell. & Sol.)	Ft. Jefferson, tiles outside moat wall	7.43	29	6.57	14
Orbicella annularis (Ell. & Sol.)	Loggerhead Key, reef, tiles	6.89	29	5.28	14
Orbicella annularis (Ell. & Sol.)	Loggerhead Key, reef, nat. att.	9.02	36	6.80	5
Orbicella annularis (Ell. & Sol.)	Golding Cay, tiles	6.45	24	5.67	12
Orbicella annularis (Ell. & Sol.)	Golding Cay, nat. att.	0	2	5	2
Orbicella cavernosa (Linn.)	Ft. Jefferson, tiles outside moat wall	14.50	19	3.22	9
Orbicella cavernosa (Linn.)	Loggerhead Key, reef, tile	4.83	6	5.67	3
Orbicella cavernosa (Linn.)	Golding Cay, tile	9.5	4	3.5	2
Favia fragum (Esper)	Ft. Jefferson, tiles, outside moat wall	4.42	27	2.92	14
Favia fragum (Esper)	Ft. Jefferson, moat	4.2	27	3.77	11
Favia fragum (Esper)	Ft. Jefferson, outside moat wall, nat. att.	6.417	6	—	—
Favia fragum (Esper)	Loggerhead Key, reef, nat. att.	4.5	8	5.00	1
Favia fragum (Esper)	Golding Cay, tiles	3.62	24	3.83	12
Manicina gyrosa (Ell. & Sol.)	Ft. Jefferson, tiles, outside moat wall	9.75	4	2.5	2
Manicina gyrosa (Ell. & Sol.)	Loggerhead Key, reef, tiles	7.87	12	4.67	6
Manicina gyrosa (Ell. & Sol.)	Ft. Jefferson, moat (transplanted)	21.50	6	8.67	3
Manicina gyrosa (Ell. & Sol.)	Ft. Jefferson, wharf	16.77	22	7.00	4
Macandra areolata (Linn.)	Ft. Jefferson, tiles outside moat wall	10.74	66	6.71	28
Macandra areolata (Linn.)	Ft. Jefferson, moat (transplanted)	15.25	12	9.60	5
Macandra areolata (Linn.)	Ft. Jefferson, outside moat wall, nat. att.	12.00	4	—	—
Macandra areolata (Linn.)	Golding Cay, tiles	7.34	26	3.64	14
Macandra labyrinthiformis (Linn.)	Golding Cay, tiles	9.17	24	4.92	12
Macandra labyrinthiformis (Linn.)	Golding Cay, nat. att.	6.375	8	7.50	2
Macandra strigosa (Dana)	Loggerhead Key, reef, tile	7.70	5	5.33	3
Macandra strigosa (Dana)	Ft. Jefferson, moat, nat. att.	19.80	5	10.00	3
Macandra strigosa (Dana)	Ft. Jefferson, wharf	11.17	6	3.50	2
Macandra strigosa (Dana)	Loggerhead Key, reef, nat. att.	9.75	8	8.75	2
Macandra strigosa (Dana)	Golding Cay, tiles	8.14	24	4.60	12
Macandra strigosa (Dana)	Golding Cay, nat. att.	5.92	14	7.50	6
Macandra clivosa (Ell. & Sol.)	Ft. Jefferson, tile, outside moat wall	20.90	10	8.83	6

NAME	STATION	INCREASE IN DIAMETER		INCREASE IN HEIGHT	
		Amount	No. of records as basis for estimate	Amount	No. of records as basis for estimate
		mm.		*mm.*	
Macandra clivosa (Ell. & Sol.)	Loggerhead Key, reef, tiles	9.41	18	4.72	9
Macandra clivosa (Ell. & Sol.)	Ft. Jefferson, moat, nat. att.	24.14	35	5.57	7
Macandra clivosa (Ell. & Sol.)	Ft. Jefferson, wharf, nat. att.	14.91	12	4.00	1
Macandra clivosa (Ell. & Sol.)	Golding Cay, tiles	5.25	4	2.50	2
Macandra clivosa (Ell. & Sol.)	Golding Cay, nat. att.	7.67	12	—	—
Mussa (*Isophyllia*) *dipsacea* Dana	Golding Cay, tiles	6.04	24	3.33	12
Mussa (*Isophyllia*) *dipsacea* Dana	Golding Cay, nat. att.	0	2	5	2
Mussa (*Isophyllia*) *rigida* Dana	Golding Cay, tiles	2.56	16	1.13	8
Mussa (*Isophyllia*) *rigida* Dana	Golding Cay, nat. att.	6.75	12	2.75	4
Siderastrea radians (Pallas)	Ft. Jefferson, tiles outside moat	3.31	29	2.37	15
Siderastrea radians (Pallas)	Loggerhead Key, reef, tiles	2.13	4	1.5	4
Siderastrea radians (Pallas)	Ft. Jefferson, moat, nat. att.	7.59	24	—	—
Siderastrea radians (Pallas)	Golding Cay, tiles	2.50	8	2.13	4
Siderastrea radians (Pallas)	Golding Cay, nat. att.	0	8	0	4
Siderastrea siderea (Ell. & Sol.)	Ft. Jefferson, tile, outside moat wall	7.71	7	2.67	3
Siderastrea siderea (Ell. & Sol.)	Loggerhead Key, reef, tiles	3.75	4	4.16	3
Siderastrea siderea (Ell. & Sol.)	Loggerhead Key, reef, nat. att.	7.41	12	5.00	1
Siderastrea siderea (Ell. & Sol.)	Golding Cay, tiles	5.05	20	2.70	10
Siderastrea siderea (Ell. & Sol.)	Golding Cay, nat. att.	4.38	8	2.50	2
Agaricia agaricites (Linn.)	Golding Cay, tiles	6.94	18	5.50	10
Agaricia purpurea LeS.	Ft. Jefferson, tiles, outside moat wall	5.67	37	3.76	17
Agaricia purpurea LeS.	Ft. Jefferson, from planulae nat. att. to tiles	8.33	6	—	—
Agaricia purpurea LeS.	Ft. Jefferson, wharf, nat. att.	17.25	8	—	—
Agaricia purpurea LeS.	Loggerhead Key, reef, nat. att.	4.84	16	—	—
Agaricia crassa Verrill	Golding Cay, tiles	2.25	8	6.50	4
Acropora cervicornis (Lam.)	Ft. Jefferson, tiles, outside moat wall	51.72	27	40.00	12
Acropora cervicornis (Lam.)	Golding Cay, tiles	—	—	45.33	6
Acropora prolifera (Lam.)	Golding Cay, tiles	44.50	18	37.17	6
Acropora palmata (Lam.)	Golding Cay, tiles	49.87	24	25.00	16
Acropora palmata (Lam.)	Golding Cay, nat. att.	95.36[2]	8	39.50	2
Porites clavaria Lam.	Ft. Jefferson, tiles, outside moat wall	20.19	50	20.45	21
Porites clavaria Lam.	Ft. Jefferson, moat, nat. att.	39.40	10	20.20	5
Porites clavaria Lam.	Ft. Jefferson, wharf, nat. att.	18.50	4	15.50	2
Porites clavaria Lam.	Loggerhead Key, reef, nat. att.	35.00	4	22.00	1
Porites clavaria Lam.	Golding Cay, tiles	18.06	42	20.25	32
Porites clavaria Lam.	Golding Cay, nat. att.	6.93	16	8.33	6
Porites furcata Lam.	Ft. Jefferson, tiles, outside moat wall	32.13	33	17.00	18
Porites furcata Lam.	Ft. Jefferson, moat, nat. att.	39.27	42	22.80	18
Porites furcata Lam.	Ft. Jefferson, wharf, nat. att.	44.75	4	16.00	2
Porites furcata Lam.	Ft. Jefferson, outside moat nat. att.	31.50	2	9.00	1
Porites astreoides Lam.	Ft. Jefferson, tiles, outside moat wall	16.19	34	5.70	15
Porites astreoides Lam.	Ft. Jefferson, moat, nat. att.	23.05	18	6.22	9
Porites astreoides Lam.	Ft. Jefferson, wharf, nat. att.	14.00	2	14.00	1
Porites astreoides Lam.	Ft. Jefferson, outside moat wall, nat. att.	13.11	9	—	—
Porites astreoides Lam.	Loggerhead Key, reef, nat. att.	10.60	25	13.28	7
Porites astreoides Lam.	Golding Cay, tiles	3.50	16	3.50	8
Porites astreoides Lam.	Golding Cay, nat. att.	7.56	16	8.75	4

but as the interspaces between the fronds are considerable in volume, comparisons with *Orbicella annularis* must be based upon relative increases in weight for a known period. The total of the weights[4] of 5 specimens of *Orbicella annularis* in 1912 was 1886 grams; the total increase in weight of the 5 specimens in 2 years was 1114 grams, or $\frac{1114}{1886} = 59.1$ per cent. The average annual increase in height of these specimens was 5.7 mm.

The total of the weights of 5 specimens of *Acropora palmata* in 1912 was 745 grams; the total increase in the weight of the same 5 specimens in 2 years was 1727 grams, or $\frac{1727}{745} = 231.8$ per cent. The average annual increase in height of these specimens was 24.4 mm.

According to weight, the specimens of *Acropora palmata* have grown 3.91 times as fast as those of *Orbicella annularis;* this may be stated in round numbers as 4 times as rapidly, while the increase in height is 4.28 times as rapid. Therefore a reef composed of *Acropora palmata* might grow upward at the rate of about an inch per year, a growth which would produce a thickness of 150 feet in $150 \times 12 = 1800$ years, but it is not probable that conditions so favorable have ever been realized in any area for a protracted period.

These two estimates give a measure of the limits of reef formation under continuously favorable conditions for upward growth. Such corals as *Orbicella annularis* might form a reef 150 feet thick in between 6500 and 7600 years; while such corals as *Acropora palmata* might form a similar thickness in 1800 years.

A few references to previous literature will indicate the rate of growth of Pacific and Indian ocean corals.

H. B. Guppy[5] has furnished interesting data on the rate of growth of corals around Keeling Atoll, including in his account the results of some experiments by G. C. Ross. According to Guppy, arborescent Acropores "grow at the average rate of four to five inches in a year, and will attain their full height in about

[4] The weights are of the wet living corals.

[5] Scottish Geog. Mag., **5**: 573–376. 1889.

fifteen years." He estimates that branching species of *Porites* grow upward at the rate of 1½ inches per year, while the annual upward growth of massive species of *Porites* is from ½ to ¾ inch per year. *Montipora*, of the facies of *M. digitata*, is said to have an upward growth of not less than five inches per year.

Stanley Gardiner and F. Wood-Jones have made valuable contributions to the knowledge of the growth rate of Indo-Pacific corals. Wood-Jones has summarized the data in a privately published paper entitled, *The rate of growth of reef building corals*. His observations in Cocos-Keeling Islands corroborate the estimates of Guppy. According to his recomputation of the data supplied by Gardiner, based on a collection of presumably 3-year old corals from Hulule, North Male Atoll, a general average of the upward growth for branching forms is about 44 mm. per year, while that of massive forms is about 29 mm. Gardiner's estimates for the upward growth of massive forms would be as follows:

Massive *"Astreidae"*	22 mm. per year
Massive *Fungidae*	29 mm. per year
Massive *Perforata*	20.3 mm. per year

As it is probable that these corals, especially the massive ones, are more than three years old, I am inclined to the opinion that the estimates for the massive species are too high. Guppy's estimate of the upward growth of massive *Porites*, 12.7 to 19.05 mm. per year, seems better founded, and falls within the range of a number of the measurements on *Porites astreoides*. However, recent remeasurements by Mayer of some of the corals measured and marked by Saville-Kent indicate an annual increase in diameter of 1.9 inches (48.26 mm.) per year. As in massive corals the increase in height is usually one-half to two-third that in diameter, the increase in height would probably be between 24 and 32 mm. per year, or very nearly the figures given by Gardiner for massive species of corals.

The data available for the Pacific corals are not so abundant as those for the Atlantic, nor have the records, with few exceptions, the same degree of precision. However, they are sufficient for some general comparisons. The general growth rate of

branching corals is nearly the same for both regions, but the growth of the massive forms in the Pacific appears to be appreciably more rapid than that of similar forms in the Atlantic. Therefore it seems probable that in the coral reef regions of the Pacific and Indian oceans a reef 150 feet thick may form under favorable conditions in less than 6000 years. According to Gardiner such a reef might form in 1000 years.

As the disappearance of the Wisconsin ice sheet is estimated to have been between 10,000 years ago in Scandinavia and Alaska and 40,000 years ago at Niagara, the data presented show that there has been ample time for the development of any known living reef since deglaciation. That Recent off-shore reefs have been formed either during or immediately subsequent to Recent submergence may be accounted established. That deglaciation was an important factor in this submergence can scarcely be doubted, but there are other factors which have not yet been evaluated.

BOTANY.—*A remarkable new Geranium from Venezuela.* PAUL C. STANDLEY, U. S. National Museum.[1]

The Geranium here described as new is of unusual interest as affording an additional evidence of the relationship which exists between the flora of the Hawaiian Islands and that of tropical North and South America. This relationship has long been known to botanists, being mentioned by Hillebrand in his Flora of the Hawaiian Islands,[2] and discussed in some detail by Alfred Russel Wallace in his "Island Life."[3] The affinities between the floras of these widely separated regions are best shown, perhaps, in the family Asteraceae: several of the genera occurring in Hawaii are represented also in tropical and subtropical North and South America, and most of the species of other genera are closely related to American plants. In other groups, also, the relationship is well shown. Hawaii possesses species of Gunnera, Phyllostegia, Fragaria, Sisyrinchium, Rubus, Dau-

[1] Published by permission of the Secretary of the Smithsonian Institution.
[2] Page XXIX.
[3] Pages 300–306.

cus, Sanicula, Portulaca, Vaccinium, Ranunculus, Osteomeles, Silene, Cleome, Nertera, Gnaphalium, Sida, Viola, Hibiscus, Drosera, Acaena, Colubrina, and Dioclea, as well as of many other genera, all of these more or less closely related to American representatives of the same groups.

Among the most interesting Hawaiian plants is a peculiar assemblage of species of Geranium, designated by Dr. Gray as the Neurophyllodea, well distinguished by their habit and by the peculiar form of their leaves. The new Geranium here described, while possibly deserving rank as a separate section of the genus, is most closely related to the Neurophyllodea, and if included in that section it is the first extra-Hawaiian species thus far discovered.

Geranium jahnii Standley, sp. nov.

A low shrub, 10 cm. high, from an elongate woody root; stems very stout, 2–3 cm. in diameter, branched, the branches ascending, the older ones nearly black, the others densely covered with the persistent stipules and petioles, the leaves present only at the apices of the branches; stipules 3–4 mm. long, lanceolate, attenuate to rigid setaceous tips; leaves densely crowded, the blades jointed with the petioles, these 1.5–2 mm. long, appressed, persistent; leaf blades cuneate, 6–8 mm. long, coriaceous, yellowish green, more or less tinged with red, glabrous, shallowly 3-lobed at the apex, the lobes triangular, acutish, the middle one longer than the others; peduncles 1-flowered, 9 mm. long, densely pilose with short spreading whitish hairs, the flowers apparently cernuous; sepals 6 mm. long, elliptic-oblong, acutish, short-mucronate, villous-ciliate, pilose, especially near the base; petals 9 mm. long, spatulate-obovate, purplish, broadly rounded or truncate at the apex, glabrous; filaments dilated at the base, the outer shorter than the inner ones; fruit not seen, the ovary densely white-pilose at the base, the beak glabrous.

Type in the U. S. National Herbarium, no. 602229, collected on the Páramo del Jabón, State of Trujillo, Venezuela, altitude 3000 to 3200 meters, October 2, 1910, by Dr. Alfredo Jahn (no. 34). The branches of the plant are covered with lichens, an indication of the humidity of the region in which it grows.

Although the material at hand is not so ample as might be desired, it is sufficient to show the proper position of this remarkable plant. Using Knuth's key to the sections of the genus,[4] which is based largely on habit, the present plant will run at once to the section Neurophyll-

[4] In Engl. Pflanzenreich, **53**: 44–47. 1912.

odea A. Gray, a group confined, so far as known heretofore, to the Hawaiian Islands. Not only in habit but in the form of the leaf blades does *Geranium jahnii* bear a strong resemblance to members of this group. Most of the species of the section have densely silvery-pubescent leaves, but in *G. cuneatum menziesii* A. Gray the leaves are glabrous and in general form much like those of the species here described, except that the blades are relatively broader and larger. Most of the species of the Neurophyllodea have a more ample inflorescence than the Venezuelan plant, but not infrequently one-flowered peduncles are found.

Knuth remarks[5] that this section is perhaps related to the group Andina, and the recent discovery of this new species tends to confirm that view. *Geranium jahnii*, however, is unlike the Andina in habit, and none of the species of that section have similar leaves. The most striking peculiarity of *G. jahnii* is the apparent articulation of the petiole with the leaf blade, a character not possessed by any other species, so far as the writer can learn, although in some of the densely cespitose species the leaf blade often does break from the petiole, which then persists upon the caudex.

[5] Op. cit., p. 216.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

GEOLOGY.—*The fauna of the Batesville sandstone of northern Arkansas.* G. H. GIRTY. U. S. Geol. Survey Bull. 593. Pp. 170, with 11 plates. 1915.

This bulletin is one of a series designed to describe and illustrate the succession of upper Mississippian faunas in the rocks of northern Arkansas, which differs surprisingly from the faunal succession of the typical Mississippian series in areas not far removed. The differences are so great that an exact correlation of the two series can not yet be made either faunally, lithologically, or stratigraphically. The Batesville sandstone overlies the Moorefield shale, whose fauna has been described in a previous bulletin. Sandstone fossils are rarely well preserved and rarely yield satisfactory results in the way of accurate generic and specific discrimination. It was therefore the fact of its occurrence in this series of formations rather than any intrinsic interest that led to the investigation of the fauna of the Batesville sandstone. The Batesville fauna had already been described by Professor Weller, whose report was based on collections from Batesville alone. The fossils described in Bulletin 593 include collections not only from the Batesville region but from Marshall as well. Weller's report recognized only about 30 species, whereas this one describes about 128, most of which are therefore new to the Batesville fauna as previously known, and some of which are new to science.

The fauna of the Batesville sandstone was found to differ widely from that of the underlying Moorefield shale and to be of upper Mississippian age, to which, indeed, it had been generally assigned. Its correlation is discussed at some length, but for the reason set down above no definite conclusion is reached as to its exact position in the typical upper Mississippian sections of Missouri and Illinois. G. H. G.

GEOLOGY.—*Fauna of the so-called Boone chert near Batesville, Ark.* G. H. GIRTY. U. S. Geol. Survey Bull. 595. Pp. 45 with 2 plates. 1915.

The Moorefield shale which is typically exposed in the Batesville quadrangle of northern Arkansas has generally been regarded as of upper Mississippian age. Its fauna comprises a unique assemblage of species remarkably different from the typical upper Mississippian faunas of Missouri and Illinois, and in some ways reminiscent of the Devonian rather than of the Carboniferous types of life. In the Batesville region the Moorefield shale rests on a series of impure limestones and cherts that have heretofore been identified as Boone limestone because of their lithologic character. The Boone limestone is commonly regarded as of Osage age and its fauna differs as widely from that of the Moorefield shale as the Moorefield fauna differs from the faunas of the typical Mississippian. Recent studies, described in this report, have shown that the cherty beds underlying the Moorefield shale near Batesville differ in lithology from the typical Boone farther west. Aside from other less striking differences they contain an intercalated bed or beds of black shale quite alien to the Boone. Moreover they contain a fauna thoroughly unlike that of the typical Boone. Fossils are hard to find in this series of cherty beds, but several small collections were obtained, aggregating about 35 species. The noteworthy feature of this fauna is that practically all the species occur also in the Moorefield shale above, some of them being characteristic Moorefield types, while practically none of them occurs in the typical Boone. This fact bears in two directions. The Moorefield shale, as defined, contains at its base a few beds of dark gray, earthy limestone; most of the formation, however, consisting of black and green shale. The basal beds, for which at one time the name "Spring Creek" limestone was proposed, furnish nearly all of what is known as the Moorefield fauna. Only a few forms have been obtained from the shaly part of the formation and these make up a fauna considerably different from that found in the "Spring Creek" limestone. It is the "Spring Creek" limestone fauna which is represented in the cherts and impure limestone below, and in view of these facts it is proposed, to restrict the name Moorefield to the shale beds of which the formation mainly consists and to unite the "Spring Creek" limestone with the underlying formation which it resembles faunally and lithologically.

The second question considered is whether the cherty beds containing the "Spring Creek" limestone fauna are really Boone or some younger formation. It is true that their fauna and lithology are dis-

tinctly different from the typical Boone fauna and lithology, but these cherty beds appear to occupy the same place in the section as the Boone which farther west, as at Marshall, immediately underlies the Moorefield shale; furthermore, in western Tennessee, there are dark shales which must be of about the same geologic age as the Boone but which contain a fauna having many features in common with the "Spring Creek" limestone fauna. This broad and very interesting problem is as yet unsettled. A conclusion so far as the cherty beds at Batesville are concerned rests partly on the thickness and faunal content of some light gray crystalline limestones that underlie the cherts in question. They are almost certainly of Carboniferous age, but are as yet uninvestigated. G. H. G.

GEOLOGY.—*The faunas of the Boone limestone at St. Joe, Ark.* G. H. GIRTY. U. S. Geol. Survey Bull. 598. Pp. 50, with 3 plates. 1915.

This short bulletin consists of two parts, one describing the fauna of the St. Joe limestone member of the Boone limestone, the other describing a small fauna obtained in the Boone not far above the St. Joe. The collections described in both papers were obtained near St. Joe in northern Arkansas.

The St. Joe limestone comprises about 30 feet at the base of the Boone limestone and though composed of much the same materials, it is faunally and lithologically a rather distinct and widely recognizable unit. Except for some shaly beds of inconsiderable thickness below, these limestones of the St. Joe are the earliest deposits of Carboniferous age in this region. The fossils described in this report, which obviously represent the typical St. Joe fauna, comprise 30 species, some of which are new. The fauna, though differing in certain respects, strongly resembles the Fern Glen fauna of northeastern Missouri, thus corroborating a correlation suggested by Professor Weller on rather incomplete evidence. Weller's correlation of the Fern Glen and Chouteau is also agreed to in this report, but it is suggested, though not stated as a conclusion, that the Chouteau may really correlate with the lower part of the Burlington limestone instead of being entirely older, as commonly held.

The small but interesting fauna from the Boone, just above the St. Joe member, comprises 32 species, many of which are new. It is noteworthy that this fauna indicates a great change in the organic sequence following St. Joe time. The succeeding fauna does not possess either a distinctive Burlington or a distinctive Keokuk facies but differs markedly from both. G. H. G.

GEOLOGY.—*The fauna of the Wewoka formation of Oklahoma.* G. H. GIRTY. U. S. Geol. Survey Bull. 544. Pp. 353, with 35 plates. 1915.

This report is purely paleontologic in treatment and had its inspiration partly in the character and fine preservation of the fossils that occur in the Wewoka formation. These circumstances have permitted the recognition of a number of new genera and species. The Wewoka formation is one of the Pennsylvanian formations of Oklahoma and is exposed in the Wewoka and Coalgate quadrangles. It consists of alternating banks of shale and sandstone, about 700 feet in all. The fossils occur in the shale beds from which they weather free. In preservation they are unusual, the lime carbonate of which they were originally composed being replaced by a compound of lime, magnesia, and iron. As at present known, the Wewoka fauna contains about 150 species, all of which are described and figured in this report. Brachiopod types are relatively few, on the other hand, pelecypods and gastropods are relatively numerous, and the cephalopods are represented by an unusually large and interesting group of species. A tentative assignment is made of the Wewoka formation to about the position of the Fort Scott limestone of the Kansas section.

G. H. G.

GEOLOGY.—*Reasons for regarding the Morrison as an introductory Cretaceous formation.* WILLIS T. LEE. Bull. Geol. Soc. Amer. **26**: 303–314. 1915.

The Morrison formation contains bones of dinosaurs which correlate it with dinosaur beds in the Potomac group of the Atlantic Coast, with the Wealden of Europe, and with certain dinosaur beds in east Africa. Marsh, who described the Morrison dinosaurs, believed that they indicated Jurassic age. Later the Potomac and Wealden beds were classed as Lower Cretaceous; the dinosaur beds of east Africa are interstratified with sedimentary rocks containing marine invertebrates, which, on preliminary examination, seem to indicate Lower Cretaceous age. There is therefore a paleontologic basis for referring the Morrison formation to the Lower Cretaceous. The present paper deals, however, mainly with physical features, which also support the reference of the formation to the Lower Cretaceous.

The problem of classification is considered from the diastrophic viewpoint. The physical relations of the Morrison to other formations are described and an attempt is made to visualize the physiographic conditions under which the formation probably developed. It is shown

that the Morrison is structurally much more closely related to the overlying Cretaceous than to the underlying formations and that its sediments were deposited on a graded plain formed mainly by degradation, but in a few places by aggradation. The formation lies with apparent conformity on marine Jurassic, but also overlaps onto a variety of older formations to such an extent as to indicate a long interval of erosion previous to Morrison time.

The sequence of events is pictured as follows: The mountains of Carboniferous time had undergone erosion throughout the Triassic period and the early part of the Jurassic, so that the encroaching sea of Upper Jurassic time found a nearly level plain extending over a large part of the Rocky Mountain region. At or near the close of the Jurassic period a slight uplift expelled this sea from the continent. This uplift, evidenced by the withdrawal of the sea, seems to have been a part of the general post-Jurassic movement which elsewhere is regarded as the close of the Jurassic period. Soon thereafter the interior of North America began to subside and the streams spread out over the graded plain the sediments which constitute the Morrison formation. These accumulated in the shallow basin lately occupied by the Jurassic sea, but also spread beyond its borders over the broad, low-lying peneplain which seems to have extended with little interruption from New Mexico to Montana and from Utah to Kansas. These streams formed the swamps, lagoons and shallow temporary lakes in which lived the huge reptiles of Morrison time. The remarkable uniformity in character and thickness of the sediments is believed to be due to the slow subsidence of a large interior area, a movement that culminated in the formation of the interior basin of the Upper Cretaceous epoch. Later this movement carried the swamp deposits beneath the level of the sea in which were deposited sediments of late Lower Cretaceous age. According to the writer's view, although the character of the sedimentation changes abruptly from the stream deposits of the Morrison to the marine deposits of the Lower Cretaceous, no long period of time intervened between them, and it follows that the Morrison is of Lower Cretaceous age.

The conclusion is reached that the physical character of the Morrison and its relation to contiguous formations indicate that it was deposited on a peneplain soon after the beginning of the Cretaceous subsidence, when the surface was too near sea level for further degradation, but not yet low enough for marine submergence. It is therefore the first sedimentary expression in the Rocky Mountain region

of the order of events that culminated in the occupancy of the interior of North America by sea waters in Cretaceous time. It is a non-marine forerunner of the Cretaceous marine formations and is of Cretaceous age. W. T. L.

GEOLOGY.—*Eocene glacial deposits in southwestern Colorado.* W. W. ATWOOD. U. S. Geological Survey Professional Paper 95–B. Pp. 13–26. 1915.

At the northwest base of the San Juan Mountains, not far from the village of Ridgway, Colorado, there is a series of exposures that include a remarkable section of glacial till, which is overlain by formations of Early Tertiary age. At the type locality, where first discovered, the till consists of 80 to 100 feet of material showing all the characters of glacial till, including an abundance of striated pebbles. This is capped by finer material probably also of glacial origin and this in turn by the Telluride conglomerate and the San Juan volcanic tuff, well known to be of Tertiary age. From the facts thus far discovered it is inferred that glaciers of the alpine and possibly also of the piedmont or small ice-sheet types existed in Eocene times in and adjacent to an early generation of San Juan Mountains. E. S. B.

ZOOLOGY.—*Die Crinoiden der Antarktis.* AUSTIN H. CLARK. Deutsche Sudpolar Expedition, XVI, Zoologie, **8**: 103–209, pl. 1–10. May 16, 1915.

This is a complete monograph of the antarctic crinoids, including an historical introduction, systematic discussion, and philosophical conclusions. Full synonymies of the families and genera, as well as of the species, are given, and diagnoses of the species, genera, and higher groups. The families Bourgueticrinidae and Plicatocrinidae and the subfamilies Zenometrinae and Heliometrinae are revised. The origin and relationship of the antarctic fauna is discussed, and the arctic and antarctic faunas are contrasted. The significance of the distribution of antarctic types in its relation to the problem of the circulation of the abyssal water is considered in detail.

One new genus, Eumorphometra, two new subgenera, Anthometra and Florometra, and three new species, *Psathyrometra antarctica*, *Eumorphometra concinna* and *Ormina occidentalis*, are described.

In the included note by J. Thiele is given a description of *Eulima capensis*, sp. nov., a parasitic gastropod found on *Cominia occidentalis;* and in a note appended, by F. W. Clarke, are given analyses of the skeletons of *Promachocrinus kerguelensis* and *Anthometra adriani*.

A. H. C.

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